Wireless IP

Strategic Technology
AirTouch Communications

W. C. Y. Lee, C. Xu and David J. Y. Lee

Abstract

The cellular network currently undergoes dramatically changes. There are a lot of interests in providing an IP-based backbone for cellular network. Such arrangement has the potential saving by routing packetised voice and data together cheaper and more efficiently. In addition, there are many IP centric applications developed for easier, faster, cheaper and user friendly adoption. However, as we push IP functions further down into cellular network, the issues of mobility management, high speed HO, SHO and roaming have to be addressed in an IP context.
The strategy is to integrate IP based standards for cellular IP solution with cellular centric vs. IP message gateway as the demarcation point. However, some unique features for cellular system might need some innovations for better performance. In this paper, we will propose 4 different solutions for different levels of cellular network IPitization. Proposal one specifies how existing IP network can be integrated with cellular network by eliminating some key hardware from traditional circuit switching architecture. Proposal two adopts the current cellular packet data network proposal with enhancement on layer 2 (ATM connections from BSS to HS). The third proposal eliminates BSC and introduces ATM support soft HO. The fourth proposal pushes IP to BTS and hopes the enhancement on QoS of IP layer will be able to support SHO.
Another area that is discussed briefly in this paper is how to integrate no IP address/stack applications (today's voice) with IP address/stack applications for IP based network by inter-working with SS7 based network.

1. Introduction

Internet traffic is growing in an exponential rate and more and more people's life are tightly coupled with Internet. A decade from now, businesses will be using data services as casual as they use voice services today [1]. Therefore, an IP-centric wireless network is essential in providing rich and efficient data services to end users. There are several proposals on how to convert current cellular network into IP arena. Although replacing the MSC with fast and powerful router seems already agreed by most vendors, there is no definite conclusion on whether and how IP should be implemented at BSC and BTS.

Before we can decide on how far IP should be pushed forward, we need to understand the functions of each cellular network element. The following are short definitions of each cellular network element's functionality. MSC functions include routing call, inter-working to PLMN and PSTN, call processing and roaming. BSC functions include

connection to MSC (A interface), mobility management, call processing and resource management. BTS functions include: signal modulation and demodulation, connection to BSC (Abis interface) and RF channel (Air interface). There are also other network elements like EIR, HLR/VLR and billing system to perform AAA (Authorization, Accounting and Authentication) related functions.

The current development in IP world has supported most of these functions. For example, mobile IP/SIP solves the mobile roaming issues, the Diameter solves the AAA issues, H.323 solves the call control and services issues, HA/FA solves the HLR and VLR issues. However, leadership in integrating these available IP-centric features as well as innovative solutions for wireless solutions are needed. One of the area is the development of cellular centric message to IP centric message gateway.

In this paper, we'll be focusing on solving the wireless part of the myth, how to support HO in a timely manner, how to support SHO and roaming.

In IS 707, two network models are proposed, the network model and the relay model. Both of them propose to have direct IP connection from mobile or user terminal to IWF (as sown in Figure 1).

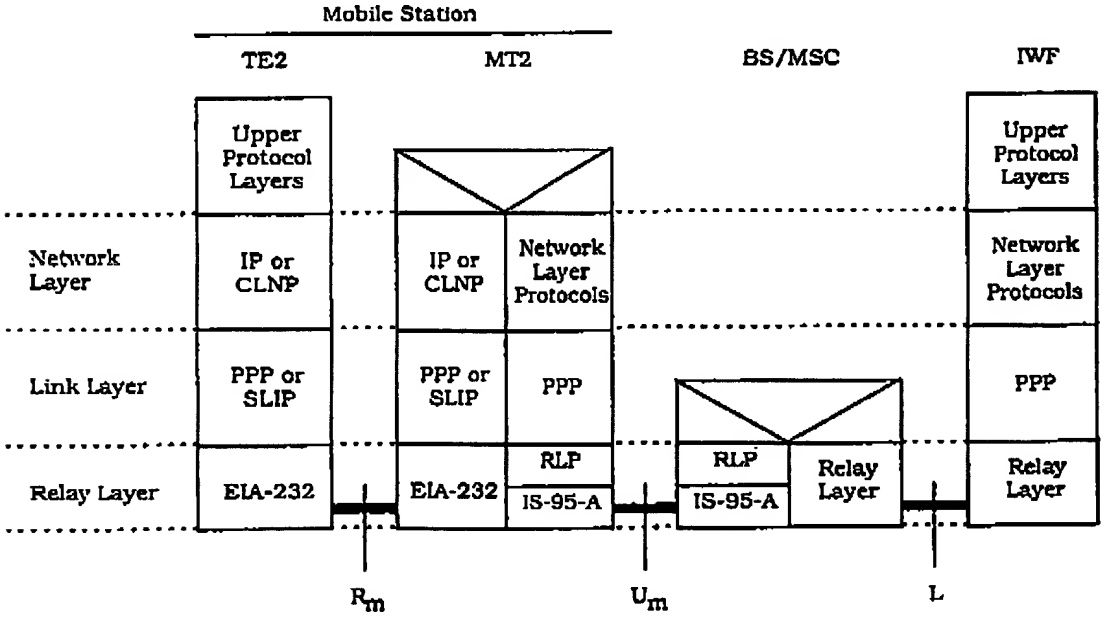

Figure 1. Network Layer R_m Interface Protocol Model

Such arrangements have minimal impact on the cellular network because all the mobility management, call processing, and roaming functions remain. However, only limited

benefits can be achieved through this architecture. More IP aggressive proposal (removing MSC and IPtizing BSC and BTS) might produce more effective cost-saving on the infrastructure and rapid wireless data adoption. This implies that mobility management, roaming and HO have to be solved in a different way, preferably in an IP-based fashion.

To fully utilize the potential of IP network, gateways for translating cellular call processing based (for example, IS634, ISUP, IS41) messages to IP based message (for example, H.323, SIP, Mobile IP, Diameter) needs to reside in the demarcation point between the cellular and IP network to support IP ready handset. To support voice over IP with traditional handset (no IP address/stack) another level of translating mobile number to IP address is needed and this can be done in two ways. One way is to have a SS7 gateway and it will be responsible for the translation among HLR and IP network. The other way is to migrate HLR to Diameter. Conceptually, both approaches are feasible and will not be discussed in the paper.

2. Network Architecture

The following figure shows current 3G architecture proposal from TR45.6[2].

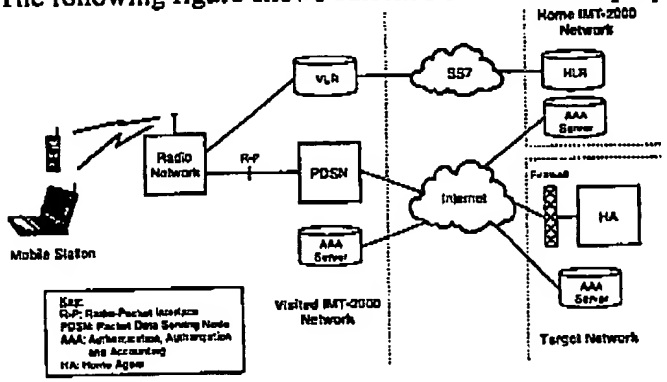

Figure 2. Current Architecture Proposal from Tr45.6

As we can see from the above Figure, the proposed architecture is not fully IPitized.

There are two areas that need to be properly addressed:

- Inter-working between IP/PLMN/PSTN so control messages and data pipe are transparent to the user (includes mapping of mobile number to TCP/IP address so that regular handset without IP stack can also run on IP network).
- Architecture proposal for wireless part of IP to ensure cellular unique features can be supported.

Inter-working between Cellular/PSTN/PLMN

As long as we can provide the interface which terminates cellular based messaging and map them into compatible IP messages, the cellular traffic can ride on the IP network. Also, depends on where the optimized location is for IP we can push the gateway to IPitize data accordingly. The following Figure illustrates the existing standard based mapping between cellular and IP networks.

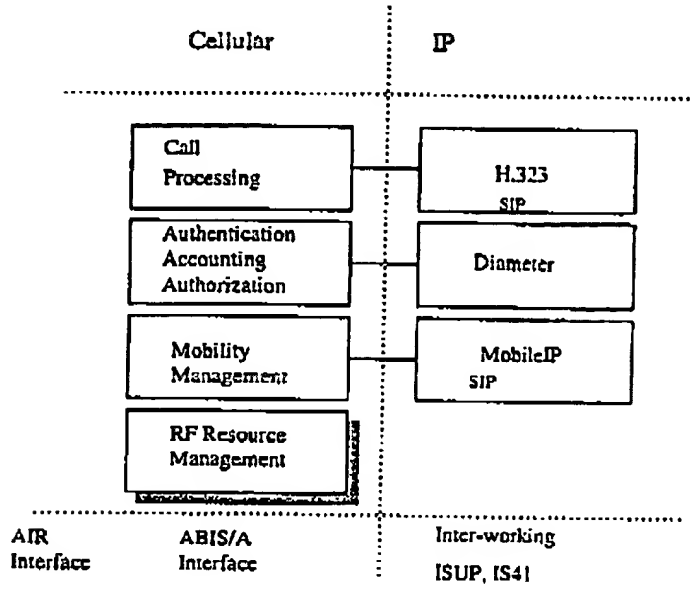

Figure 3. Mapping Between Cellular and IP

We need to access what are available and can be integrated between cellular and IP networks. In traditional cellular system the BSC is responsible for mobility management, call processing and radio resource management. BSC also has the following hardware, transcoder, vocoder and switch. It is possible to replace these hardware and functionality by router and additional software/hardware (DSP based). The MSC functionality includes call setup, connection and features, routing, authentication and accounting. These functionality can also be replaced by existing IP protocols and applications (H.323/SIP for call set up and connection, Diameter for accounting, authentication and authorization). Mobility function can be replaced by mobile IP/SIP through tunneling between HA and FA and HO can be supported through tunneling also. SHO in CDMA system can be supported by using the existing ATM protocols.

IS 95 call processing, mobility management and resource management related messages need to be translated and reIPitized to IP based message. The key issue is CDMA SHO. This issue can be solved by adopting ATM into cellular network. ATM supports multimedia application and QoS. It is not optimized in capacity with small bandwidth. As more and more cellular frequencies are allocated for data services and convergence of voice and data (multimedia), the statistical gain by combining all cellular frequencies

might make it worthwhile to implement ATM in cellular network. The ATM Virtual Tributary is a very inefficient way of emulating circuit switching network. However, VPI/VCI approach has proven to be more effective in a wider bandwidth environment. Also, network management overhead is imbedded in the ATM/SONET header in the existing proposal. Current TR45.5 proposal supports PPP on top of RLP. PPP allows direct connection from point to point and is the most efficient mean of connecting two point in the network. Although IP community is enhancing MPLS for VPN and QoS, it is difficult to achieve the QoS provided by ATM since IP is connectionless originated. Another issue needs to be addressed is the mapping from Mobile number to IP address This can be done by gateway responsible for phone numbers and IP addresses.

Wireless IP Architecture

Four different network architectures are proposed and will be discussed in detail in the next Section.

1. Replace BSC functionality with application specific router
   - Eliminate unnecessary HWs
   - Both data and voice ride on IP pipe
   - MSC is eliminated and SS7 related messages will be reIPitized at BSC and routed to IP network.
   - IP connection is establish from BSC to mobile (for data)
   - BSC has link layer connection for voice application
   - Intra-BSC HO is maintained through BSC mobility management functions
   - Inter-BSC HO is implemented through inter-BSC tunneling

2. Enhance BSC to have ATM connection to HS
   - FA remains a function of BSC
   - Established ATM connection from BSC to BTS to HS;
   - Intra-BSC/Inter-BSC HO is maintained through ATM layer functionality
   - ATM connection from BSC to BTS to support SHO

3. Enhance BTS to have ATM functionality
   - Eliminate BSC
   - BTS supports ATM and QoS can be achieved by synchronizing BTSs involved in SHO by using nail up connection
   - FA remains at BTS
   - Establish IP connection between mobile and BTS, mobile and HO server
   - SHO will be supported through SHO server
   - Intra-BSC HO is maintained through virtual IP connection

4. Enhance BTS to have IP functionality and BSC/FA functionality
   - Established IP connection from BTS to TE2
   - Inter-BTS HO is maintained through BTS tunneling and updating HA
   - SHO might be an issue

3. Wireless IP Architecture Proposals

3.1 Replace BSC with Router

In this model, MSC is removed and BSC/router is enhanced with IP routing and FA functions. The interface between BTS and BSC remains the same. Intra-BSC handoff is handled as before since all mobility management functions still remain in BSC. From BSC to network, it is all IP-based. In addition, FA is added to BSC to handle the tunneling between HA and FA. Inter-BSC hand-off is done by first FA anchoring during the handoff, and HA updating when completing the handoff.

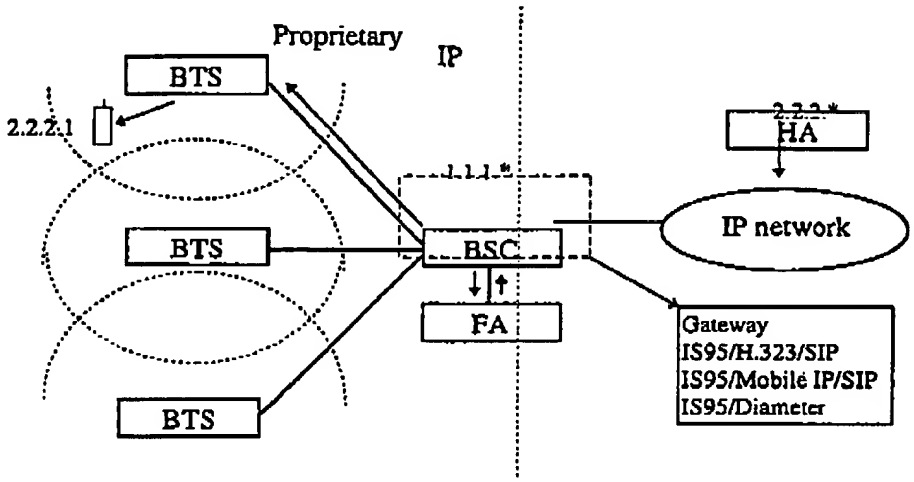

Figure 4. Packet reception

As shown in Figure 4, packet destined for mobile (IP address 2.2.2.1) will be routed from HA (IP address 2.2.2.*) through FA (IP address 1.1.1.*). When intra BSC handoff occurs, the FA does not change, and therefore no impact on IP network.

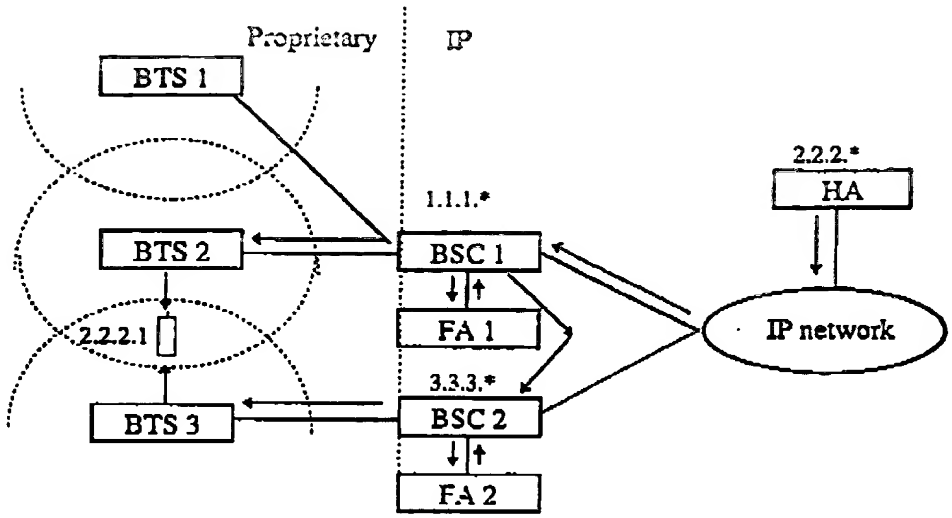

Figure 5. Inter-BSC Handoff

When inter BSC handoff occurs, the incoming packet is routed from HA (IP address 2.2.2.*) through FA1 (IP address 1.1.1.*), FA2 (IP address 3.3.3.*) and finally delivered to mobile. When HO is complete. the HA has been updated with the new FA address (FA2 in this case).

In this architecture, the voice service (assume handset does not have IP stack) will be supported by:

- Convert CDMA voice packet to voice over IP coding scheme with DSP (QCELP/G.729) and transmitted through the IP route set up by H.323.
- Mobile to mobile call can be supported with no vocoding between two mobiles.
- Control messages (call processing related, IS634 in this case) will be translated into H.323 messages
- If user terminal support IP stack, H.323 will be set up all the way to user terminal.

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3.2 ATM Connection Between BSC/BTS/HS

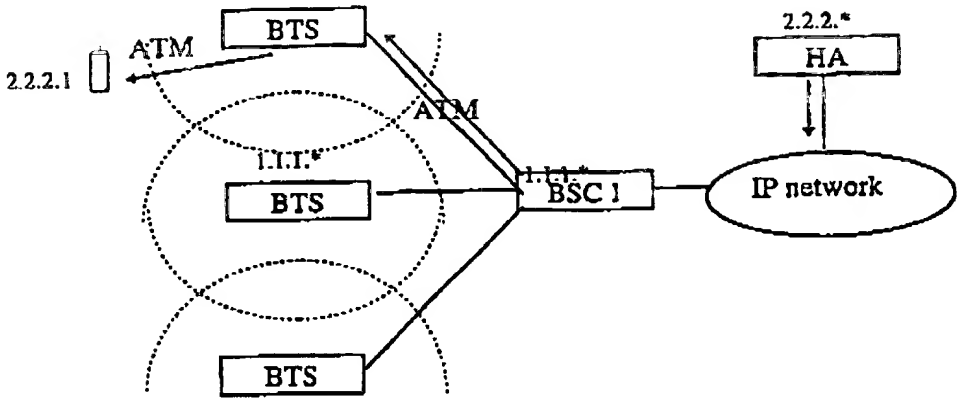

Figure 6 Intra BSC HO

ATM will be used as layer 2 from BTS to support more flexible QoS and multimedia services. With this architecture, the soft handoff can be easily resolved.

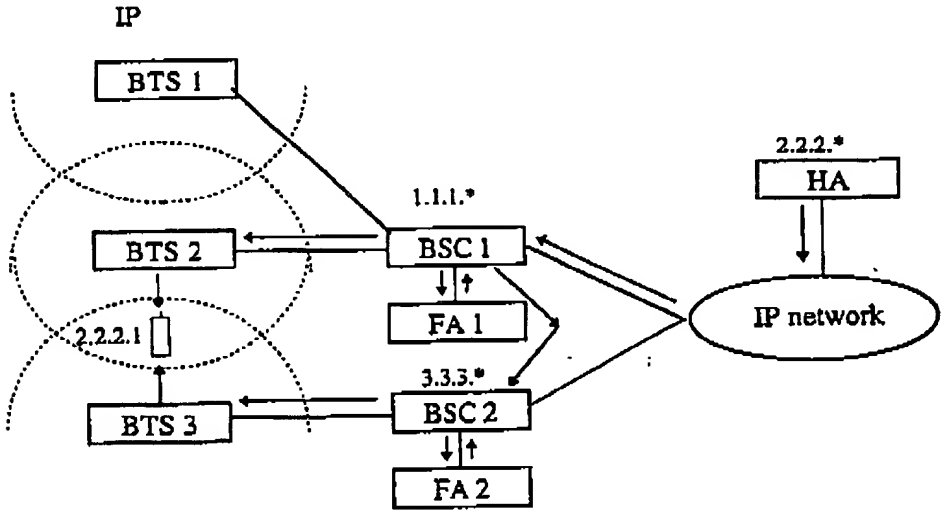

Figure 7 Inter BSC HO

3.3 BTS ride IP on ATM with HO server (no BSC)

When we push IP stack into BTS, the issue of soft HO arises because there is no way to guarantee layer 3 packet synchronization at present time. Utilization of virtual IP on top of ATM, the path is switched from VP1, VP2 to VP3, therefore, there is only one IP hop

between soft HO server and user terminal and transmit synchronization can be easily achieved. At this proposal, the IP is running on top of ATM layer. The BSC will also be eliminated from the network. There will be direct ATM as well as IP connections from BTS to HS. This approach is pushing the ATM to BTS layer so that SHO can be supported more effectively. BSC functionality needs to be pushed to BTS. With connection oriented natural and supporting QoS, it is possible to eliminate the BSC from the network.

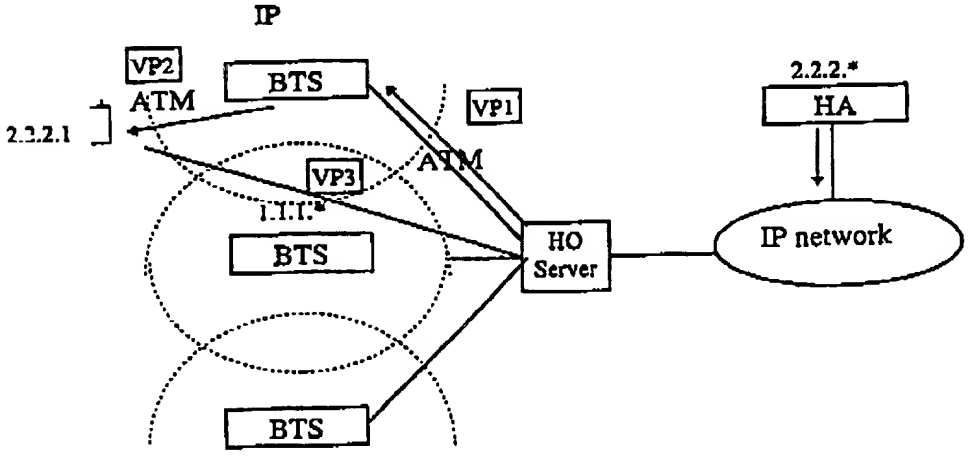

Figure 8. No SHO State

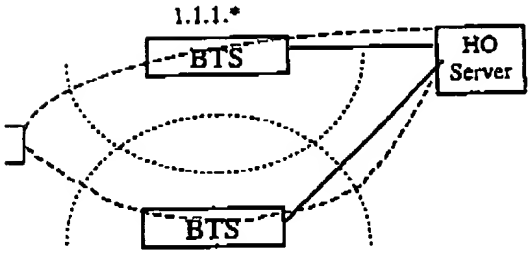

Figure 9. In SHO

3.4 BTS with IP (independent of layer 2 protocol)

With more and more enhancement to IP layer on QoS it is possible for IP to support most features that are supported by ATM (distributed HO solution). With wider bandwidth IP network might also be able to support more time critical or QoS sensitive applications. SHO might not be able to work in this distributed HO architecture since QoS on IP layer is still under development.

3.4.1 Intra FA Handoff (FA Update)

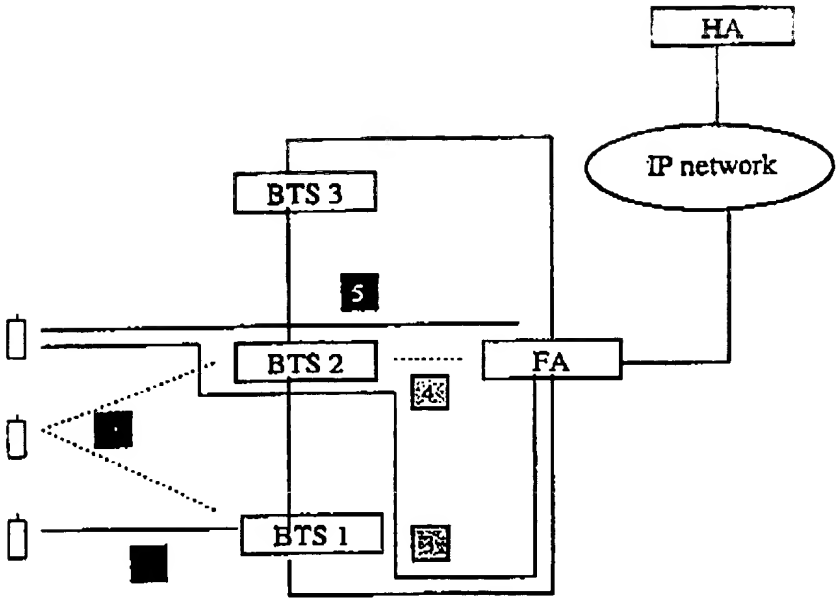

Figure 10 Intra FA HO through FA Update

1.BTS establishes IP connection with mobile
2.Mobile detects BTS2 for HO and sending HO message to both BTSs
3.Mobile is served by BTS2 by anchoring at BTS1
4.BTS2 sends location update to FA for mobile
5.Mobile IP packet now is delivered through BTS2

3.4.2 Intra FA HO (HA Update)

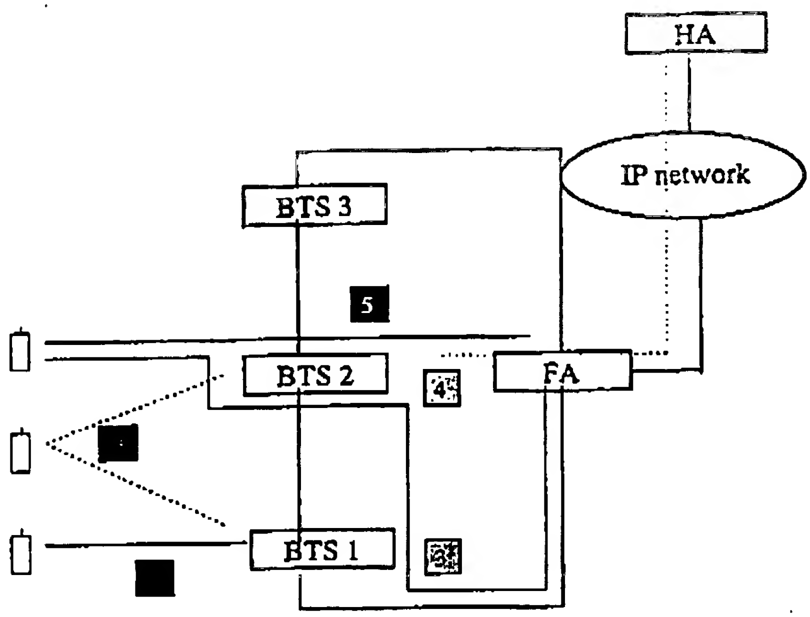

Figure 11 Intra FA HO through HA Update

1.BTS establishes IP connection with mobile
2.Mobile detects BTS2 for HO and sending HO message to both BTSs
3.Mobile is served by BTS2 by anchoring at BTS1
4.BTS2 sends location update to HA for mobile location update
5.Mobile IP packet now is delivered through BTS2

3.4.3 Inter FA HO

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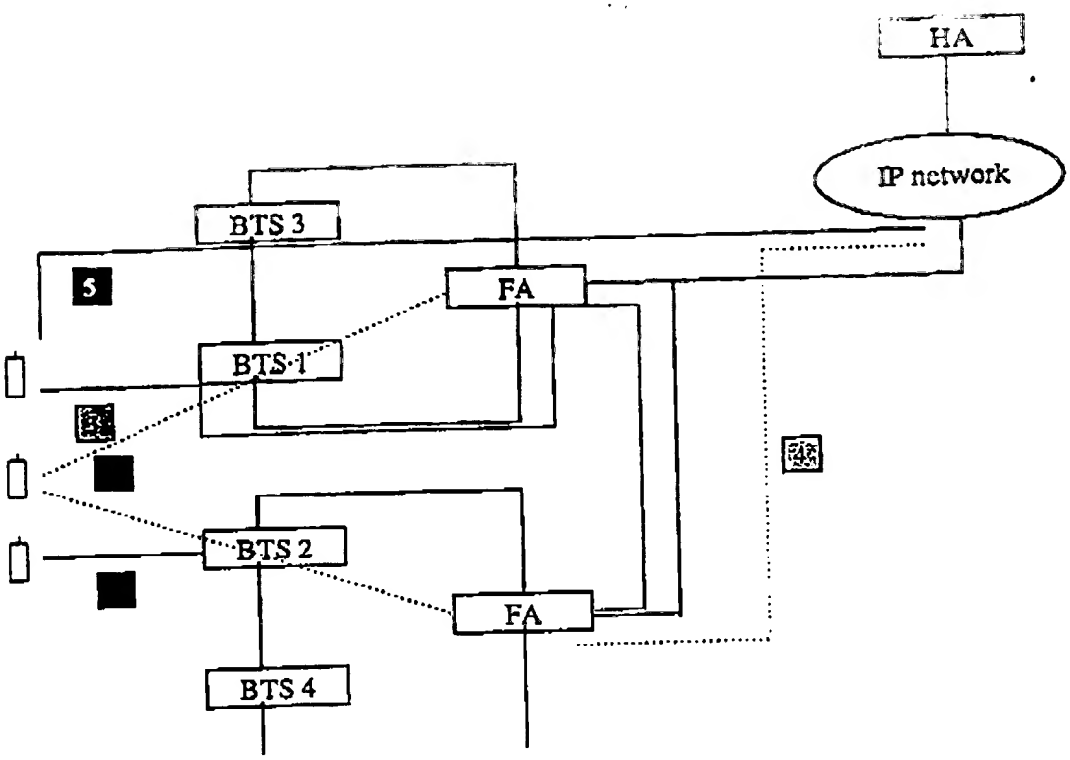

Figure 12 Inter FA HO

1.BTS establishes IP connection with mobile
2.Mobile detects BTS2 for HO and send HO message to both BTSs
3.Mobile is served by BTS2 by anchoring at BTS1
4.BTS2 sends location update to HA for mobile location update
5.Mobile IP packet now is delivered through BTS2

4. Migration Strategy and Potential Benefits

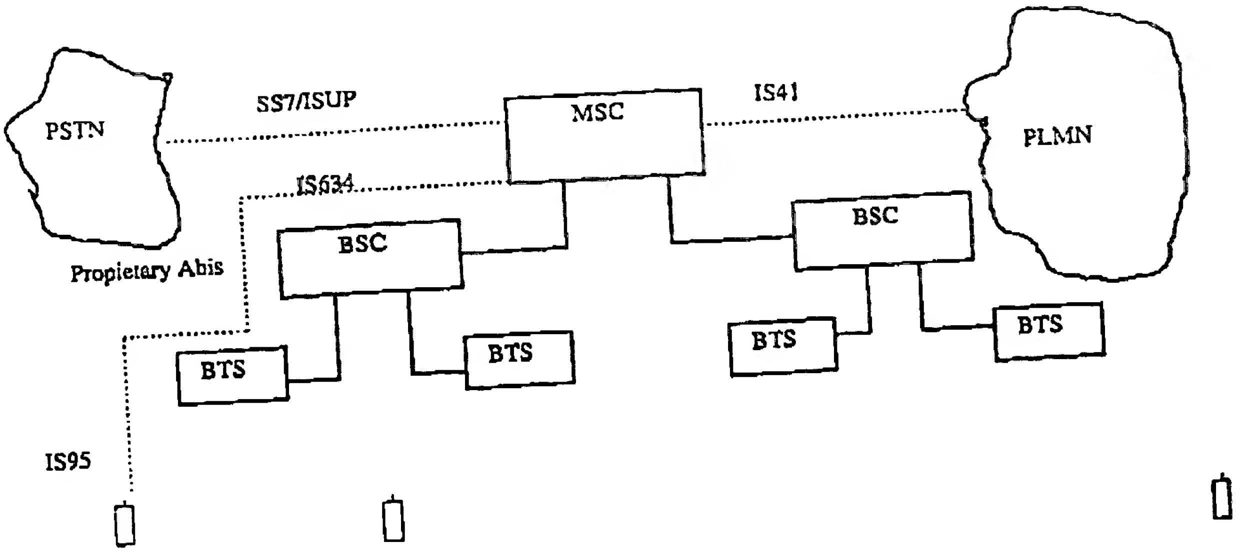

Figure 13. Current Network Architecture

Migration strategy needs to be developed for existing cellular operators to painlessly transfer from current architecture to the future network architecture.

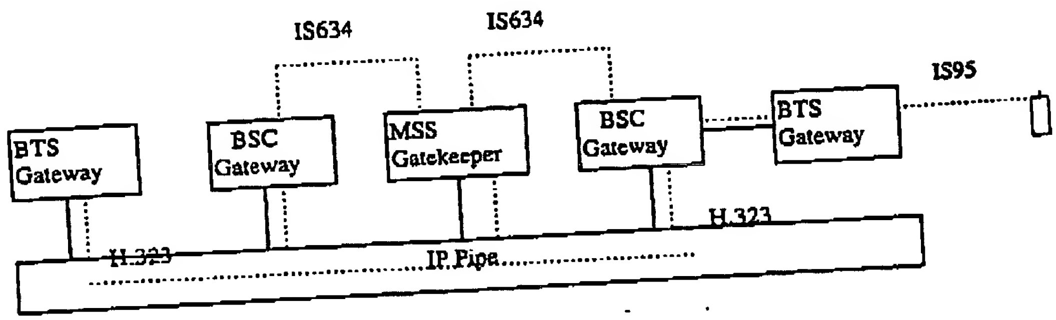

Figure 14. Migration Stage 1 IP at BSC

Stage 1. Transform current infrastructure to IP backbone for voice and data

- This needs the co-existing of both IP and SS7 based networks
- PLMN network element platform can be shifted to PC/router/DSP based platform
- Transform current backbone to private managed IP for more efficient data transferring
- Maintain current call processing signaling on existing PLMN infrastructure
- Transmit voice and data by using the IP pipe
- Reduce further infrastructure investment
- Set up migration foundation for next generation backbone

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Stage 2. Push IP as close to user as possible.

- Integrating existing SS7 related features into IP based paradigm.
- Merge existing PLMN network element into IP network
- Single IP network to cover PLMN and other network traffic
- Taking advantages of available and exploding IP network and features

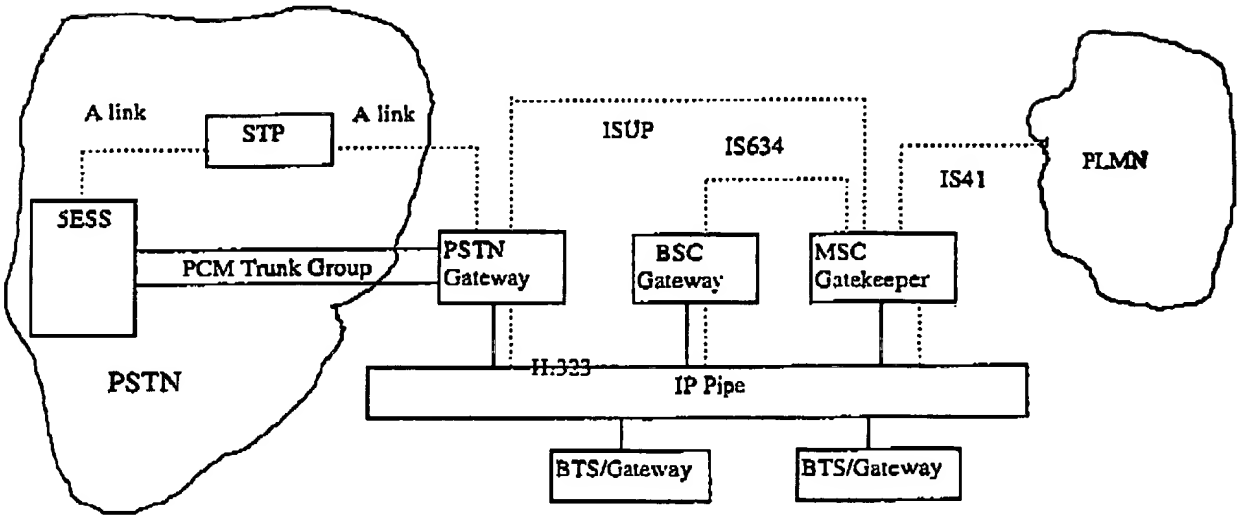

Figure 15 Migration Stage 2 IP at BTS

Stage 3. Ride on VPN for wireless data

- After inter-working functionality are fully integrated (SS7, H.323, ISUP, IS41,..), cellular traffic can eventually running on VPN to VPN with guaranteed QoS and time of arrival.
- This is the ultimate fully integrated wireline and wireless networks.

The main benefits of pushing IP stack down the network chain as far as possible are:

- Unified network management interface
- Availability of applications
- Economic of scale
- Efficient use of bandwidth

5. Conclusion and Future Work

This paper presents four proposals on migrating cellular network to IP based network. The traditional issues associated with cellular network (mobility, call processing, HO, AAA, voice and data services) are addressed in a high level by integrating several

standard proposals in the IP/cellular industries. These proposals need to be reviewed jointly with IP as well as cellular vendors to ensure that the optimized network architecture can be in place in the near future. One of the potential area for future work is to follow the enhancement of the IP layer for wireless application. With QoS enhancement at IP layer and wider bandwidth, it is possible to have a total IP solution (all network element in PLMN is IP based) that support soft hand off. With the advancement in IP network, one potential network solution for cellular operators might just be subscribing VPN among all BTS for guaranteed services (routing, HO, call processing) and BTS will just be router with RF equipment.

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[4]. Internetworking with TCP/IP Volume 1 Principles, Protocols and Architecture, Douglas E. Comer, Prentice Hall, 3rd edition, 1995